Computation of Passive Robustness Bound for Assembly/Disassembly Processes

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Abstract

Works presented in this paper deal with the robustness of manufacturing job-shops with time constraints. A computing algorithm of a lower bound of the maximal time disturbances allowed in a given point is provided. To demonstrate the effectiveness and accuracy of this algorithm, two industrial examples are depicted. The possession of this bound allows checking the death of marks without the generation of too many false alarms. From a practical point of view, the death of a mark corresponds to an incorrect treatment of a given product. In food or pharmaceutics industries, this scenario is not acceptable because it jeopardizes health of humans. When a disturbance is lower than the bound value, the production remains correct and no quality alarm is generated.

Keywords

P-time Petri Net; Manufacturing System; Passive Robustness; Sojourn Time Constraints; Time Disturbance

Introduction

This paper deals with control over manufacturing workshops with time constraints. The considered systems have a robustness property which allows maintaining products quality when there are time disturbances (Jerbi et al, 2009). The robustness is defined as the capability of the system to preserve the specifications when confront some expected or unexpected variations. Thus, the robustness characterizes the capacity to deal with disturbances. The robustness is interpreted into different specializations. The passive robustness is based upon variations included in validity time intervals. There is no control loop modification to preserve the required specifications. On the other hand, active robustness uses observed time disturbances to modify the control loop in order to satisfy these specifications. During the past decade, several approaches have dealt with manufacturing workshops with time constraints (Jerbi et al, 2004), (Atto et al, 2008). For example, in Jerbi (2004), a computation of the local passive robustness of a given path is built up. Moreover, an algorithm computing a lower bound of the maximal time disturbances allowed on a given point was provided. Since, the result of the algorithm is a lower bound.

The work presented in this paper focuses on the robustness of workshops with/without assembling tasks, regarding time disturbances. More precisely, we aim at computing the value of passive robustness bounds for some systems characterized with synchronization and delay phenomena. Among the broad variety of applications concerned, one can cite transportation systems and production systems. The contribution of this paper is the application of a computing algorithm with a lower bound of the maximal time disturbances to workshops with/without assembling tasks.

The remainder of this paper is organized as follows. Section 1 begins with the definition of a P-time Petri net model and its functional decomposition. Section 2 gives some basic definitions concerning robustness of Discrete Event Systems (DES). Then, the local robustness of a given path in the workshop is analytically built up. Moreover, an algorithm computing a lower bound of the maximal time disturbances allowed on a given point is provided. Finally, in order to show the effectiveness of this algorithm, an application of the proposed algorithm to two manufacturing workshops is outlined and results are discussed.

Modelling tools of DES Integrating Time Constraints

P-time Petri Net

Definition 1 (Khansa et al, 1996): The formal definition of a P-time Petri net is given by a pair < R; I > where:

R is a marked Petri net,
IS: $P \rightarrow Q^{+} \times (Q^{+} \cup \{+\infty\})$
$p_i \rightarrow IS_i = [a_i, b_i]$ with $0 \leq a_i \leq b_i$.

IS_i defines the static interval of holding time of a mark in the place p_i belonging to the set of places P (Q^{+} is the set of positive rational numbers). A mark in the place p_i is taken into account in transition validation when it has stayed in p_i at least a duration a_i and no longer than b_i. After the duration b_i the token will be dead.

Notations

- $p°_i$ (respectively $°p_i$): the output transitions of the place p_i (the input transitions of the place p_i),
- q_{ie}: the expected sojourn time of the token in the place p_i,
- q_i : the effective sojourn time of the token in the place p_i,
- $St_e(n)$: the nnd expected firing instant of the transition t,
- St(n): the nnd effective firing instant of the transition t,
- T_C: the set of controllable transitions,
- T_S: the set of synchronization transitions.

Functional Decomposition

As the sojourn times in places have not the same functional signification when they are included in the sequential process of a product or when they are associated to a free resource, a decomposition of the Petri net model into four sets is made using (Long, 1993), where:

- R_U is the set of places representing the used machines,
- R_N corresponds to the set of places representing the free machines
- $Trans_C$ is the set of places representing the loaded transport resources,
- $Trans_{NC}$ is the set of places representing the unloaded transport resources (or the interconnected buffers),
- $Trans_C$ is the set of places representing the loaded transport resources.

Passive Robustness

Basic Definition

Definition 2 (Jerbi et al 2004): Let us consider a discrete event system and G the associated Petri net model. Let us call B(G) the behaviour of G corresponding to the trajectory that states successively reached. Let C(B(G)) be the schedule of conditions established on the system behaviour B(G). C(B(G)) is materialized by a series of constraints which must be checked by B(G). A non respect of B(G) corresponds to a violation of C(B(G)). It is said that a subset SG of G is robust to a disturbance δ if and only if ∀ n∈SG, and that the occurrence of the disturbance δ at the node n does not involve a violation of C(B(G)).

Definition 3 (Collart Dutilleul, 2007): The passive robustness corresponds if no change in control is necessary so that the properties specified by the schedule of conditions are preserved in the presence of disturbance.

Definition 4 (Collart Dutilleul, 2007): A mono-synchronized subpath Lp is a path containing one and only one synchronization which is its last node.

Definition 5: An elementary mono-synchronized subpath is a mono-synchronized subpath beginning with a place p such as °p is a synchronization transition.

Definition 6: It is said that a path Lp has a local passive robustness on $[\delta_{min}, \delta_{max}]$ if the occurrence of a disturbance $\delta \in [\delta_{min}, \delta_{max}]$ at any place $p \in Lp$ does not involve a token death at synchronization transitions of Lp.

Figure 1, shows an elementary mono-synchronized subpath Lp= (p_{112}, t_{112}, p_{122}, t_{12}) with different notations.

Definition 7 (Jerbi et al, 2009): The time passive rejection capacity interval of a path Lp is RC(Lp) = [Ca(Lp), Cr(Lp)] where:

$$Ca(Lp) = \sum_{p_i \in Lp \cap (R_N \cup Trans_{NC})} (q_{ie} - b_i), \quad (1)$$

$$Cr(Lp) = \sum_{p_i \in Lp \cap (R_N \cup Trans_{NC})} (q_{ie} - a_i). \quad (2)$$

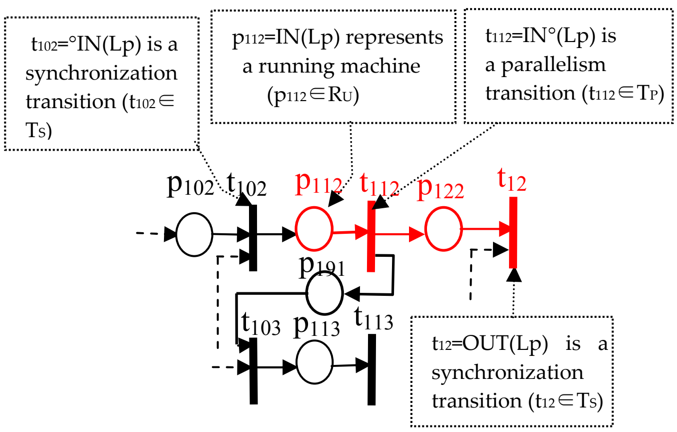

FIG. 1 AN ELEMENTARY MONO-SYNCHRONIZED SUBPATH WITH DIFFERENT NOTATIONS

Passive Robustness Computation

To compute local passive robustness interval, the concept of compensable and transmissible margin is introduced.

The compensable margin and the transmissible margin on the mono-synchronized subpath Lp_k are denoted as Δrc_k and Δrt_k respectively.

The local passive robustness delay Δr_{Lpk} can be calculated using formulas (3), (4) and (5) (Collart Dutilleul et al, 2007).

$$\Delta r_{Lp_k} = \Delta rc_k + \Delta rt_k \tag{3}$$

With:

$$\Delta rc_k = \sum_{p_i \in Lp_k \cap (R_N \cup Trans_{NC})} (q_{ie} - a_i) \tag{4}$$

$$\Delta rt_k = \min_{\substack{p_i^o = OUT(Lp_k) \\ p_i \notin Lp_k}} (b_i - q_{ie}) \tag{5}$$

1) Computation Algorithm of the Lower Value of Passive Robustness for a Delay

In order to avoid the violation of schedule conditions, a recursive algorithm allowing computing a lower bound of the maximal time disturbances allowed in a given point of manufacturing workshops is presented.

a) Algorithm (Jerbi et al, 2004)

$\varphi = \{Lp_j / (n° = IN(Lp_j)) \wedge (Lp_j \in C_{ms}) \wedge (Lp_j \in G)\}$

$Marge \Leftarrow \min_j [\Delta rc_j + F(G \setminus Lp_j, OUT(Lp_j)°, \min_{p^o_i = OUT(Lp_j),\ p^o_i \notin Lp_j} (b_i - q_{ie}))]$

F(G*, p*, Δrt)

{

$\varphi^* = \{Lp_j / (p^* \in Lp_j) \wedge (Lp_j \in C_{se}) \wedge (Lp_j \in G^*)\}$

If ($\varphi^* == \Phi$ ou $\Delta rt == 0$) alors ($F \Leftarrow \Delta rt$)

Else

{

$F \Leftarrow \min_j \{\min[\Delta rt, (\Delta rc_j + F(G^* \setminus Lp_j, OUT(Lp_j)°, \min_{p^o_i = OUT(Lp_j),\ p^o_i \notin Lp_j} (b_i - q_{ie})))]\}$

}

}

2) Description of the Algorithm

The algorithm behaves in such a way:

- Select the node where we want to calculate the passive robustness margin,
- Build the set of mono-synchronized subpaths (φ) defined as follows:

$\varphi = \{Lp_j / (n° = IN(Lp_j)) \wedge (Lp_j \in C_{ms}) \wedge (Lp_j \in G)\}$

- Calculate the passive robustness margin associated to the set of subpaths φ,

- Remove the elementary mono-synchronized subpath for the construction of the whole φ* defined as follows:

$\varphi^* = \{Lp_j / (p^* \in Lp_j) \wedge (Lp_j \in C_{se}) \wedge (Lp_j \in G^*)\}$

- Compute for each mono-synchronized subpath of φ*, the passive robustness margin F defined as follows:

$F \Leftarrow \min_j \{\min[\Delta rt, (\Delta rc_j + F(G^* \setminus Lp_j, OUT(Lp_j)°, \min_{p^o_i = OUT(Lp_j),\ p^o_i \notin Lp_j} (b_i - q_{ie})))]\}$

- Stop the algorithm if the following condition is satisfied:

$(\varphi^* == \Phi$ ou $\Delta rt == 0)$ alors $(F \Leftarrow \Delta rt)$

Illustrative Examples

Milk Production Unit (Job Shop with Assembling Tasks)

1) Presentation of the Workshop

Figure 2, shows a milk manufacturing unit in repetitive functioning mode, composed by six machines (M_1, M_2, M_3, M_4, M_5, M_6) and seven conveyors (T_1, T_2, T_3, T_4, T_5, T_6, T_7), where:

– M_1 is a bottle filling machine,
– M_2 is a milk bottle capper,
– M_3 is a time/date stamp,
– M_4 is an hydromat,
– M_5 is a labelling machine,
– M_6 is a packaging machine.

To manufacture product (bottle of 1000 ml), empty bottles (group of 6) are placed on the conveyor T_1 to supply the bottle filling machine M_1. Once this operation is completed, the filled bottles are transported towards the capping machine M_2 by the conveyor T_2. After capping, the bottles arrive directory on T_3, then this conveyor carries the bottles to the machine M_3 (time/date stamp) to print the manufacturing date and end date of consumption.

The bottles leave the machine M_3 on a conveyer T_4 towards the machine M_4 (Hydromat). The hydromat ensures the sterilization of milk which is heated to sterilization temperature 140°–150°C. After sterilization, cooling takes place using a cold water tank and atmospheric air. As a result, the milk does not require refrigeration and has a relatively longer shelf life (3 to 6 months at ambient temperature) with an excellent safeguarding of the vitamins and original qualities. Once this task is completed, the bottles are transferred to the labelling machine M_5 via the conveyor T_5. Next; the bottles arrive to the packaging machine M_6, where they will be wrapped by welding in a group of 6. Lastly, the finished product is deposited on the conveyor T_7 towards the stock of finished products SA.

2) Modeling of Milk Production Unit

P-time Petri nets are convenient tools to model manufacturing systems whose activities times are included between a minimum and a maximum value. Figure 3 shows a P-time Petri net (G) modeling a milk production workshop and its functional decomposition. The obtained G is used to study the robustness of the considered manufacturing workshop (Long, 1993).

3) Computation of the Lower Value of Passive Robustness in Milk Manufacturing Workshop

In Table I, we can quote the following examples of the compensable margin and the transmissible margin associated to some mono-synchronized subpaths Lp_k of the P-time Petri net model (Figure 3).

Let us take the P-time Petri net as example, Figure 3 associated to milk manufacturing unit.

The application of the algorithm at the node t_9, in Figure 4, allows computing a lower value of passive robustness margin equal to 10 (Margin= 10).

In fact, according to the recursive algorithm, the set of mono-synchronized subpaths (φ) is defined as follows (Figure 4):

$\varphi = \{Lp_j \,/\, (n°=IN(Lp_j)) \wedge (Lp_j \in C_{ms}) \wedge (Lp_j \in G)\}$

$\varphi = \{Lp_0=(p_9, t_9, p_{18}, t_8); Lp_1=(p_9, t_9, p_{101}, t_{101}); Lp_2=(p_9, t_9, p_{102}, t_{102}); Lp_3=(p_9, t_9, p_{103}, t_{103}); Lp_4=(p_9, t_9, p_{104}, t_{104}); Lp_5=(p_9, t_9, p_{105}, t_{105}); Lp_6=(p_9, t_9, p_{106}, t_{106})\}$.

TABLE I Compensable margin and transmissible margin associated to some mono-synchronized subpaths of G

Path	Δrt_k	Δrc_k
$Lp_0=(p_9, t_9, p_{18}, t_8)$	6	689
$Lp_1=(p_9, t_9, p_{101}, t_{101})$	$+\infty$	0
$Lp_2=(p_9, t_9, p_{102}, t_{102})$	$+\infty$	0
$Lp_3=(p_9, t_9, p_{103}, t_{103})$	$+\infty$	0
$Lp_4=(p_9, t_9, p_{104}, t_{104})$	$+\infty$	0
$Lp_5=(p_9, t_9, p_{105}, t_{105})$	$+\infty$	0
$Lp_6=(p_9, t_9, p_{106}, t_{106})$	$+\infty$	0
$Lp_7=(p_{111}, t_{111}, p_{191}, t_{102})$	56	5
$Lp_8=(p_{112}, t_{112}, p_{192}, t_{103})$	41	3
$Lp_9=(p_{113}, t_{113}, p_{193}, t_{104})$	28	3
$Lp_{10}=(p_{114}, t_{114}, p_{194}, t_{105})$	19	2
$Lp_{11}=(p_{115}, t_{115}, p_{195}, t_{106})$	12	4
$Lp_{12}=(p_{116}, t_{116}, p_{196}, t_{101})$	71	36

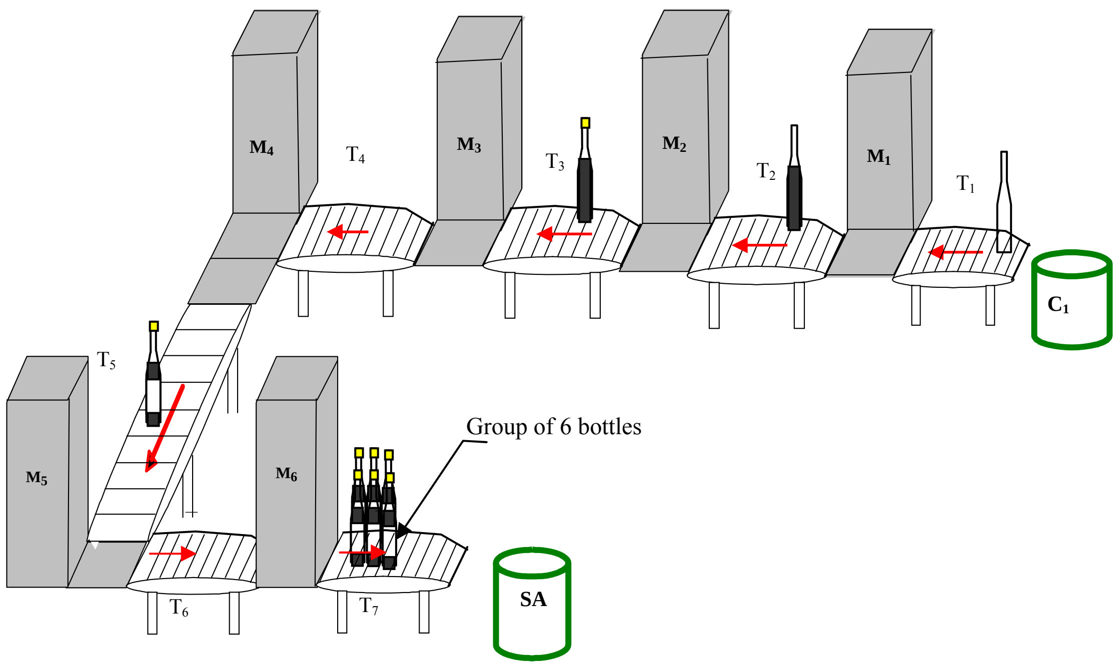

FIG.2 MILK MANUFACTURING UNIT

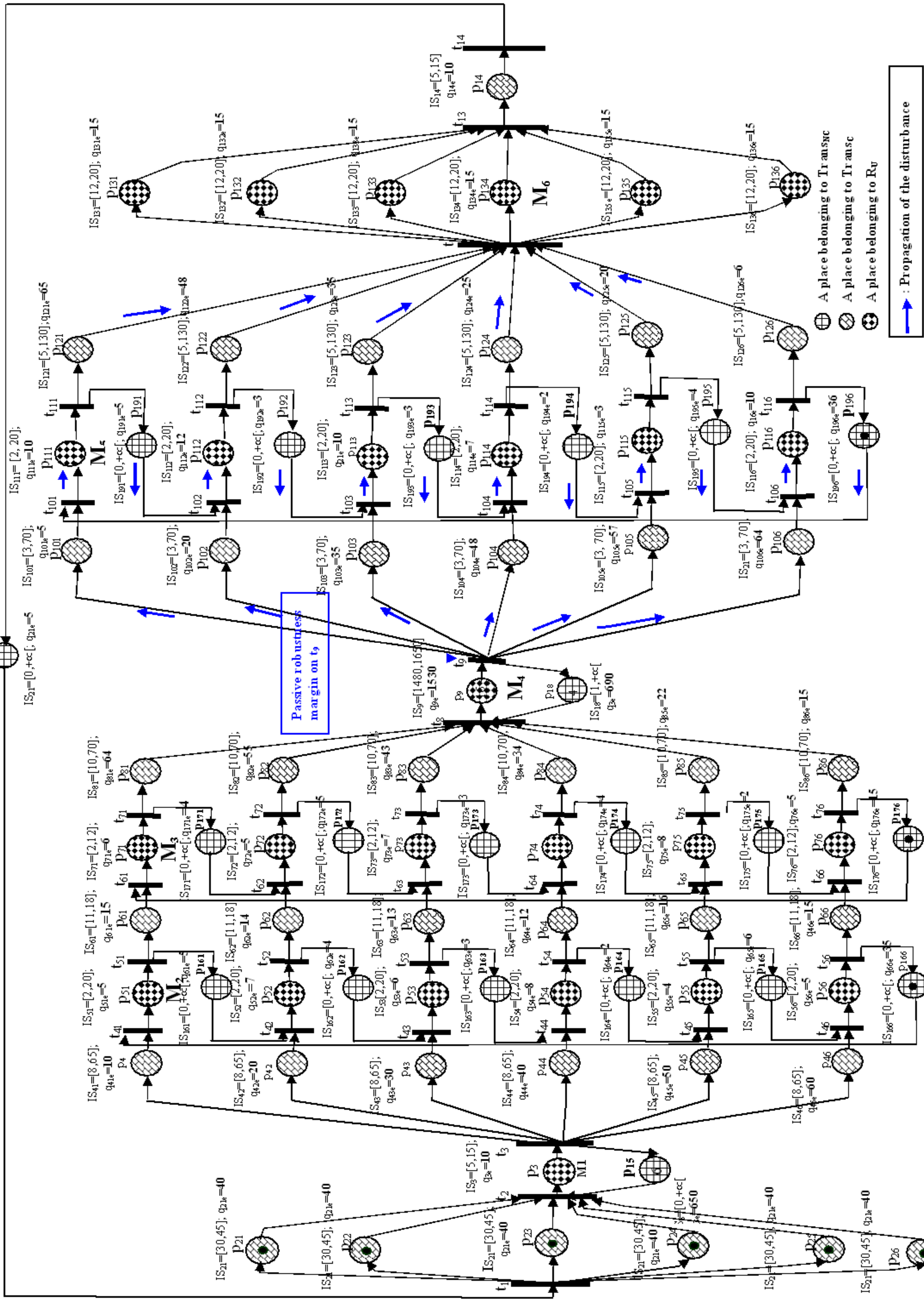

FIG. 3 A MILK MANUFACTURING UNIT MODELLED BY A P-TIME PETRI NET

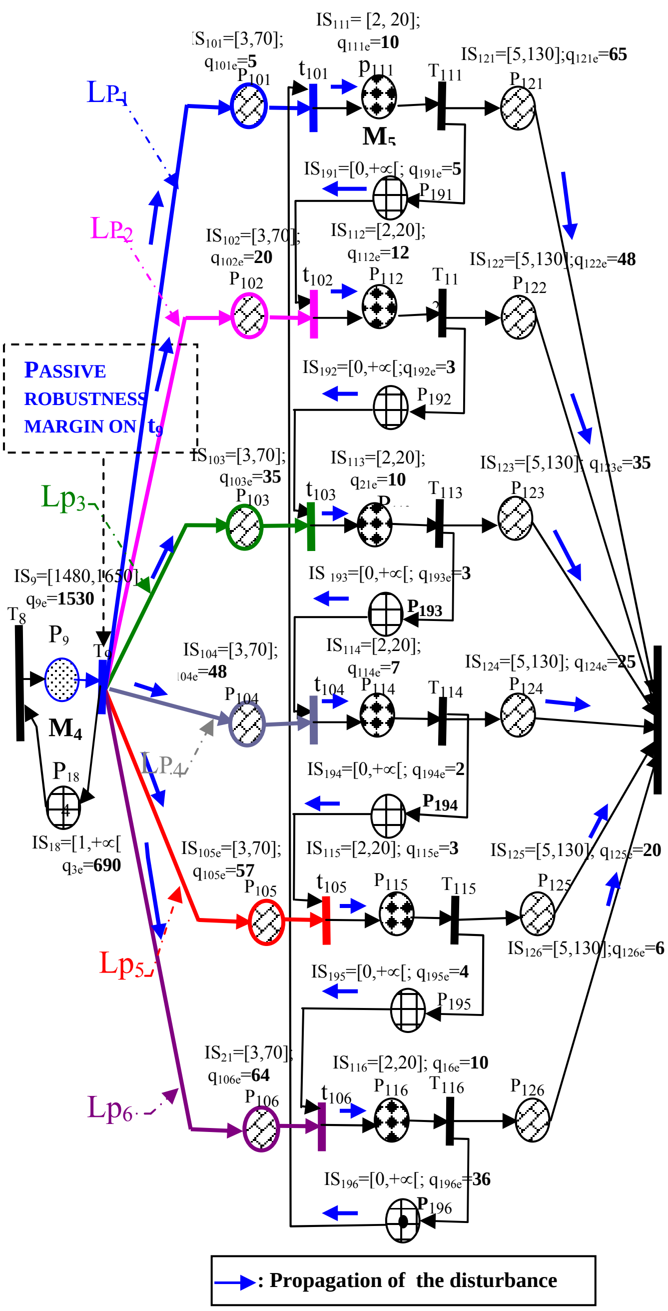

FIG. 4 EXAMPLE OF DISTURBANCE PROPAGATION: CASE OF PASSIVE ROBUSTNESS

The full set of margins associated to each mono-synchronized subpath is summarized in table II. The lower bound of passive robustness margin is equal to 10 ($F \Leftarrow \min$ [Margin 1, Margin 2, Margin 3, Margin 4, Margin 5, Margin 6]).

Let us illustrate the local margin associated to the path Lp_1.This margin equals 23 time units;

– On the path Lp_1, the disturbance change passively the firing instant of the transition t_9 and also the sojourn time in the place p_9: $St_9(n)=St_{9e}(n)+23$ and $q_9=q_{9e}+23=1553$.

TABLE II Passive margin associated to mono-synchronized subpaths

Margin	Expression	Value
Margin1	Margin 1 $\Leftarrow \min [\Delta rc_1 + F(G\backslash Lp_1, OUT(Lp_1)^{\circ}, \min(b_{196}-q_{196e}))]$ $p^{\circ}_{196}= OUT(Lp_1)$ Margin 1 $\Leftarrow \min [0+ F(G\backslash Lp_1, p_{111}, +\infty)]$	**Margin1⇐23**
Margin2	Margin 2 $\Leftarrow \min [\Delta rc_2 + F(G\backslash Lp_2, OUT(Lp_2)^{\circ}, \min(b_{191}-q_{191e}))]$ $p^{\circ}_{191}= OUT(Lp_2)$ Margin 2 $\Leftarrow \min [0+ F(G\backslash Lp_2, p_{112}, +\infty)]$	**Margin2⇐18**
Margin3	Margin 3 $\Leftarrow \min [\Delta rc_3 + F(G\backslash Lp_3, OUT(Lp_3)^{\circ}, \min(b_{192}-q_{192e}))]$ $p^{\circ}_{192}= OUT(Lp_3)$ Margin 3 $\Leftarrow \min [0+F(G\backslash Lp_3, p_{113}, +\infty)]$	**Margin3⇐15**
Margin4	Margin 4 $\Leftarrow \min [\Delta rc_4 + F(G\backslash Lp_4, OUT(Lp_4)^{\circ}, \min(b_{193}-q_{193e}))]$ $p^{\circ}_{193}= OUT(Lp_4)$ Margin 4 $\Leftarrow \min [0+ F(G\backslash Lp_4, p_{114}, +\infty)]$	**Margin4⇐12**
Margin5	Margin 5 $\Leftarrow \min [\Delta rc_5 + F(G\backslash Lp_5, OUT(Lp_5)^{\circ}, \min(b_{194}-q_{194e}))]$ $p^{\circ}_{194}= OUT(Lp_5)$ Margin 5 $\Leftarrow \min [0+ F(G\backslash Lp_5, p_{115}, +\infty)]$	**Margin5⇐10**
Margin6	Margin 6 $\Leftarrow \min [\Delta rc_6 + F(G\backslash Lp_6, OUT(Lp_6)^{\circ}, \min(b_{195}-q_{195e}))]$ $p^{\circ}_{195}= OUT(Lp_6)$ Margin 6 $\Leftarrow \min [0+ F(G\backslash Lp_6, p_{116}, +\infty)]$	**Margin6⇐106**

– After the crossing of the transition t_{101}, the disturbance is transmitted to the two paths $Lp_7=(p_{111}, t_{111}, p_{191}, t_{102})$ and $Lp_{13}=(p_{111}, t_{111}, p_{121}, t_{12})$ through the starting place p_{111}.

– On the path Lp_7, the disturbance is partially rejected in p_{191} ($Cr(Lp_7)=5$) and the mark is available in p_{191} with a delay time equals to 18. This delay is accepted in p_{102} since the available control margin for a delay accepted is equals to 50 ($IS_{102}=[3, 70]$, $q_{102e}=20$). The firing instant of the transition t_{101} is $St_{101}(n)=St_{101e}(n)+18$ and the residue ($\delta'=18$) is transmitted to the two paths $Lp_8=(p_{112}, t_{112}, p_{192}, t_{103})$ and $Lp_{14}=(p_{112}, t_{112}, p_{122}, t_{12})$ through the place p_{112}.

– On the path Lp_8, the residue of disturbance is partially rejected ($Cr(Lp_8)=3$), and this delay is acceptable on p_{103} since the passive transmissible margin on the mono-synchronized subpath Lp_3 is 35 ($IS_{103}=[3, 70]$, $q_{103e}=35$).

– The residue $\delta''= 15$ is propagated towards the three paths $Lp_9=(p_{113}, t_{113}, p_{193}, t_{104})$, $Lp_{10}=(p_{114}, t_{114}, p_{194}, t_{105})$ and $Lp_{11}=(p_{115}, t_{115}, p_{195}, t_{106})$. It is easily to check that this residue is partially rejected by these tree paths since $Cr(Lp_9)=3$, $Cr(Lp_{10})=2$, and $Cr(Lp_{11})=4$.

– The token is available in p_{195} with a delay time equals to 6. There is no death of mark in p_{106} since

we can accept a maximum delay time equal to 6 (IS_{106}=[3, 70], q_{106e}=64). Therefore, the occurrence of the disturbance δ at the node t_9 does not involve a violation of C(B(G)).

Multi-product Job-shops without Assembling Tasks

Figure 5 shows a P-time Petri net (G) modeling a system composed of two sequential processes GO_1 and GO_2 with two shared machines (M_1, M_2).

The full set compensable margin and the transmissible margin associated to some mono-synchronized subpaths Lp, in Figure 5, are summarized in Table III.

The application of the algorithm at the node t_5, in Figure 5, allows computing a passive robustness margin (lower bound) equal to 6 (Margin=6). It is easily to check that the occurrence of the disturbance at the node t_5 does not involve a violation of C(B(G)).

- The residue δ''= 15 is propagated towards the three paths Lp_9=(p_{113}, t_{113}, p_{193}, t_{104}), Lp_{10}=(p_{114}, t_{114}, p_{194}, t_{105}) and Lp_{11}=(p_{115}, t_{115}, p_{195}, t_{106}). It is easily to check that this residue is partially rejected by these tree paths since Cr(Lp_9)=3, Cr(Lp_{10})=2, and Cr(Lp_{11})=4. The token is available in p_{195} with a delay time equal to 6. There is no death of mark in p_{106} since we can accept a maximum delay time equal to 6 (IS_{106}=[3, 70], q_{106e}=64). Therefore, the occurrence of the disturbance δ at the node t_9 does not involve a violation of C(B(G)).

Margin $\Leftarrow$ F(G\Lp′, p_2, +∞)

φ^* = {Lp_3, Lp_4} et (L_1= Lp′∪Lp_3 ; L_2= Lp′∪ Lp_4)

$$F \Leftarrow \min \begin{cases} \min[+\infty, F(G\backslash Lp'\backslash Lp_3, p_4, +\infty)] \\ \min[+\infty, 5+F(G\backslash Lp'\backslash Lp_4, p_{13}, 1)] \end{cases}$$

Step 1: Computation of F(G\ Lp′\Lp_3, p_4, +∞)

φ^* = {Lp_6}

$F \Leftarrow \min[+\infty, 5+F(G\backslash Lp'\backslash Lp_3\backslash Lp_6, p_{11}, 3)]$

Step 1.1:Computation of F(G\ Lp′\$Lp_3$\$Lp_6$, p_{11}, 3)

φ^* = {Lp_7, Lp_8}

$$F \Leftarrow \min \begin{cases} \min[3, 8+F(G\backslash Lp'\backslash Lp_3\backslash Lp_6\backslash Lp_7, p_4, 5)] = 3 \\ \min[3, F(G\backslash Lp'\backslash Lp_3\backslash Lp_6\backslash Lp_8, p_{13}, +\infty)] \end{cases}$$

Step 1.1.1: Computation of F(G\ Lp′\$Lp_3$\$Lp_6$\$Lp_8$, p_{13}, +∞)

φ^* = {Lp_1, Lp_2}

$$F \Leftarrow \min \begin{cases} \min[+\infty, 18+F(G\backslash Lp'\backslash Lp_3\backslash Lp_6\backslash Lp_8\backslash Lp_1, p_{11}, +\infty)] \\ \min[+\infty, 7+F(G\backslash Lp'\backslash Lp_3\backslash Lp_6\backslash Lp_8\backslash Lp_2, p_2, 9)] \end{cases}$$

Step1.1.1.1: Computation of F(G\Lp′\$Lp_3$\$Lp_6$\$Lp_8$\$Lp_1$, p_{11}, +∞)

$\varphi^* = \Phi$ then $F \Leftarrow +\infty$

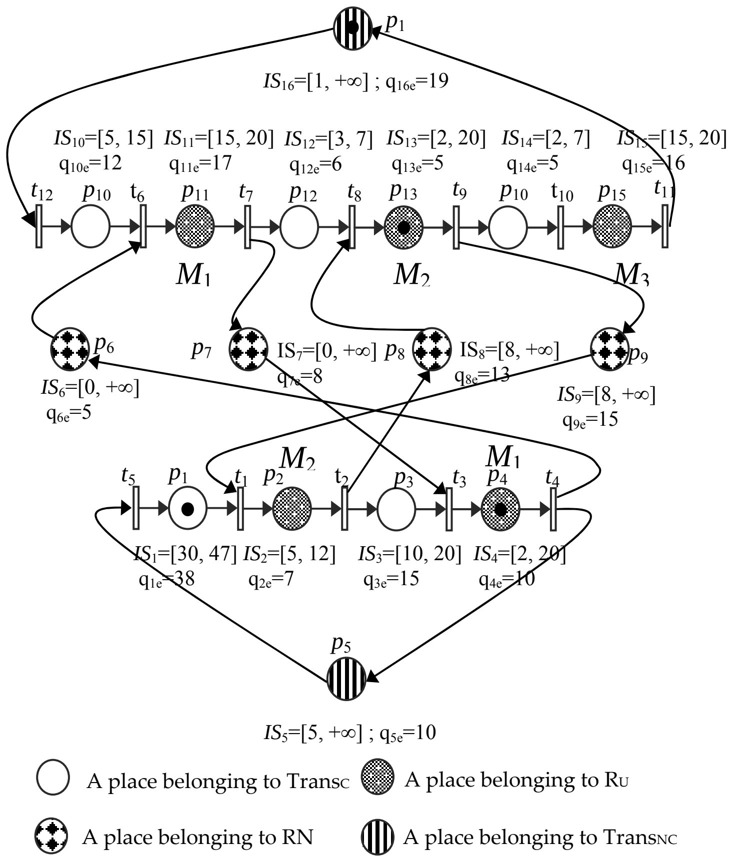

FIG. 5 AN HILLION LIKE MODEL

TABLE III PASSIVE MARGIN ASSOCIATED TO MONO-SYNCHRONIZED SUBPATHS

Path	Δrc_k	Δrt_k
Lp_1=(p_{13}, t_9, p_{14}, t_{10}, p_{15}, t_{11}, p_{16}, t_{12}, p_{10}, t_6)	8	+∞
Lp_2=(p_{13}, t_9, p_9, t_1)	7	9
Lp_3=(p_2, t_2, p_3, t_3)	0	+∞
Lp_4=(p_2, t_2, p_8, t_8)	5	1
Lp_5=(p_4, t_4, p_5, t_5, p_1, t_1)	9	+∞
Lp_6=(p_4, t_4, p_6, t_6)	5	3
Lp_7=(p_{11}, t_7, p_7, t_3)	8	5
Lp_8=(p_{11}, t_7, p_{12}, t_8)	0	+∞

Step 1.1.1.2: Computation of F(G\Lp′\$Lp_3$\$Lp_6$\$Lp_8$\$Lp_2$, p_2, 9)

$\varphi^* = \Phi$ then $F \Leftarrow 9$

Step 2: Computation of F(G\ Lp′\Lp_4, p_{13}, 1)

φ^* = {Lp_1, Lp_2}

$$F \Leftarrow \min \begin{cases} \min[1, 18+F(G\backslash Lp'\backslash Lp_4\backslash Lp_1, p_{11}, +\infty)] = 1 \\ \min[1, 7+F(G\backslash Lp'\backslash Lp_4\backslash Lp_2\backslash Lp_8, p_2, +\infty)] = 1 \end{cases}$$

The lower bound of passive robustness is equal to 6 (Margin $\Leftarrow$ 6)

Conclusion

The local robustness of a given path in the workshops is analytically built up. Moreover, an algorithm computing a lower value of the maximal time disturbances in manufacturing system with and without assembling tasks is provided.

The use of this lower value improves the monitoring of the industrial processes with time constraints, increasing the productivity and reducing the maintenance costs by improving the availability of the production systems.

Based on two workshops topology, it can be claimed that the computed bound allows checking the death of marks without the generation of many false alarms.

The algorithm has to be studied from a computing complexity point of view in order to figure out if it is really scalable and compatible in the general case.

The computing of the lower value of passive robustness in manufacturing workshops with assembling tasks should be paid attention due to its capability in the elimination of unobservable set of disturbances (Mhalla et al, 2010a), (Mhalla et al, 2010b). Since the passive robustness is based upon variations included in validity time intervals, there is no control loop modification to preserve the required specifications. Indeed, the computing of a lower bound of passive robustness interval allows solving the false alarm problem but not the avoidance of constraint violation.

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